PATENT SPECIFICATION 803,650

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International Classification :—B23n. C23c.

COMPLETE SPECIFICATION.

Improvements in or relating to Components for Operation at High Temperature.

We, THE BIRMINGHAM SMALL ARMS COMPANY LIMITED, of Armoury Road, Small Heath, Birmingham 11, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to components for operation at high temperature, of the type in which internal ducts are provided for the passage of gaseous or liquid coolant through the heat- and corrosion-resistant metal of the components, to enable them the better to withstand the action of the hot fluids to which the surfaces of the components are exposed. It is desirable that the channels are of relatively small cross-section and occupy a position near the surface where they do not unduly affect the mechanical strength of the component, as is particularly important, for example, at the fixing root of a turbine blade. Moreover, the controlled placing of the ducts near the hot working surface enables the coolant to be most effectively used.

According to the present invention, a method for the production of heat- and corrosion-resistant components provided with cooling ducts includes the steps of forming channels in the surface of a core, filling the said channels with a temporary solid filling, building up a sheath of heat- and corrosion-resistant metal by spraying over the filled core, removing the temporary filling from the channels to leave ducts between the sheath and the core, and sintering the sprayed core to effect diffusion between the sprayed sheath and the surface of the core between the channels, whereby there is produced a component having an impermeable unitary coating bridging the channels in the core and secured to the surface of the core between channels by diffusion.

The sheath is built up to a thickness sufficient for it to provide a stable outer part of the component, bridging the ducts. An excess thickness of sheath may be built up, to allow for final shaping and sizing of the component to the required contour by machining and/or grinding, and/or for polishing the outer surface.

The invention also includes sheathed and ducted heat- and corrosion-resistant components in which the sheath is a sprayed metal unitary coating bridging channels in the core and diffused by sintering to the surface of the core between the channels.

An important advantage of the invention is that the sheath forms a unitary seamless envelope of homogeneous metal and effectively encases the component. No welded or brazed joints are necessary, as is the case with sheaths of pre-formed sheet material.

The core may be made of any desired quality of heat-resisting steel or alloy, made from the solid material or by powder metallurgy technique, and the sheath may be formed by spraying a steel or alloy similar to the core, or any other heat-resisting or high-melting metal or alloy.

The sprayed sheath may be formed to full thickness in one continuous spraying operation, or alternatively can be formed by stages in separate continuous spraying operations, preferably with sintering after each operation. It is often convenient to remove the filler

from the channels before the full thickness has been applied. In some cases, sintering of a sheath built-up to partial thickness may be the means of bringing about removal of the filler. If applied in stages, the successive layers are not necessarily of the same heat- and corrosion-resistant metal. Moreover, the successive layers may follow interlayers of sprayed material, e.g. a boride or a boron-containing alloy as described in our Patent Application No. 30242/55 (Serial No. 803,649), serving to promote diffusion between the layers as the result of the sintering, and thus to promote good adhesion. The spray is conveniently applied by means of a spray gun fed with metal or alloy either in the form of powder or in the form of wire.

The filler should be of material capable of withstanding the temperature arising in the metal-spraying operation. Advantageously, the core is highly heated in vacuo as an immediate preliminary to being sprayed, and the material of the filler must then withstand this elevated temperature. Where the material of the filler is not capable of withstanding the temperature of preheating, the filler is introduced into the channels after the preheating in vacuo.

Particularly but not exclusively where the channels change direction one or more times, they may be filled after preheating with a refractory paste containing a metal capable of being distilled at high temperature but able to withstand the temperature arising in spraying. A preferred paste comprises zinc oxide and zinc particles and a relatively small amount of plaster of Paris, the zinc oxide and zinc preferably being present in about equal parts by weight. A little borax may be advantageously included to retard the setting. A very effective composition consists of :—

zinc oxide ..	42½	parts by weight		
zinc filings ..	42½	,,	,,	,,
plaster of Paris	14.75	,,	,,	,,
borax	0.25	,,	,,	,,

the whole being mixed with a little water. Such a filler does not significantly change in condition up to 1000° C. when heated in air. When heated in vacuo or in hydrogen, the zinc oxide is reduced to metallic zinc, and this, with the zinc filings, volatilises, leaving a residue of finely powdered calcium sulphate (from the plaster of Paris), capable of being shaken or blown from the ducts. The filler may be removed simultaneously with sintering of the sheath material. The volatilised zinc requires to be trapped to avoid its clogging the vacuum pump.

Where no pre-heating before spraying is used, or when the filler is introduced after preheating, the filler may be a metal capable of being distilled off at a moderate temperature, e.g. cadmium which may be distilled in vacuo at a temperature in the range 500° C. to 700° C. Zinc may likewise be used. Again, a relatively low-melting metal or alloy may be used. Such metals or alloys may be used in channels which change direction one or more times to form ducts from which the filler must be able to flow away in vaporised or molten form.

However, if the final form of any duct permits, for example shallow ducts having leads-out to the surface of the component, tougher material of high melting point such as copper, aluminium, or steel wire may be used as a filler and can be introduced before preheating. Such fillers are capable of withstanding without melting the sintering temperatures employed and therefore they can be left in position until after sintering, but they are preferably withdrawn intact after spraying and before sintering. This material is embedded in the channel by a refractory cement, e.g. alumina cement, to secure it in place, and to prohibit adhesion of the sprayed coating to the metal filler. Such a cement may also be used to secure wires of softer material, such as cadmium and zinc, which are removed by distillation.

The internal corners of the channels are preferably rounded to discourage fatigue cracks arising at any sudden change of section under the mechanical stress (accompanied by high temperature) to which the component is subjected in use. The external corners of the channels are also preferably rounded. This rounding should be applied even if the channels have undercut sides.

The channels in the core may lead directly to a duct in the root mounting for the supply of gaseous or liquid coolant, or may be connected together by one or more cross-channels, e.g. at the root end of a turbine blade, for connection in turn to the said duct in the root mounting. In the case of a shrouded blade, the core channels may be similarly connected either directly or through one or more cross-channels to a duct in the shroud to complete the coolant circuit. One end of each channel or each cross channel may be allowed to open to the surface of the blade for deliverate escape of the coolant into the turbine atmosphere.

The invention will now be described in greater detail with reference to the production of a ducted gas turbine blade with a sintered sprayed metal coating applied with the aid of a paste filler as described above. Diagrammatic drawings illustrating the said production have been appended hereunto. In the drawings :—

Figure 1 is a detached section through a gas turbine blade which has reached a stage in the production where it is ready for application of the said coating ;

Figure 2 is a detached section through a finished ducted blade;

Figure 3 is a plan view from above of part of a finished blade; and

Figure 4 is a detached side view in section taken on line IV—IV of Figure 2.

Figures 3 and 4 are drawn to a reduced scale compared with that of Figures 1 and 2.

A blade core 1, consisting of the blade proper 2, and at least an anchoring root 3 (Figures 3 and 4) (but, if required, a shroud also, not shown) is formed of heat- and corrosion-resistant steel or other similar alloy, e.g. the alloy known as "Nimonic 90" ("Nimonic" is a Registered Trade Mark) believed to be of composition 15% to 21% Co, 18% to 21% Cr, up to 5% Fe, 0.1% C, 0.8% to 2% Al, 1.8% to 3% Ti, and the balance Ni. The blade 2 has its usual aerofoil section smaller than that finally required, by an allowance of say 0.020" to 0.050" all round. Longitudinal channels 4 are formed, by any suitable known method, e.g. milling, in the surface of the blade 2 wherever a duct is required. In general, the main length of a channel is straight, see Figure 3, and each channel has a lead-out at that end of the blade 2 which is remote from the root 3. In the subsequent coating of the blade 2; the leads-out can either be protected against being covered by blanking off, or by the filling projecting beyond the core surface. Some or all of the channels, as illustrated in Figures 3 and 4, change direction to direct them to a main duct 7 in the root 3, a cross-channel 5 (shown in dot-and-dash lines) being provided to connect any of the channels 4 which do not lead directly into the duct 7 with those which do. The cross-channel 5 has ducts 6 leading to the main duct 7. Where the blade has a ducted shroud (not shown), the arrangement by which the channels lead into the main duct of the shroud may be similar. The bottom of each channel 4 has rounded corners, and the outer edges of the channels 4 are rounded into the surface of the core (see Figures 1 and 2). This surface is roughened by any convenient method, for example shot blasting, ready to receive the sprayed coating forming the sheath. Although comparatively narrow channels have been shown in the drawings, wide shallow grooves are often preferable for effective cooling of the completed blade.

The channelled core is preheated in vacuo to a high temperature, e.g. 1250° C. and after cooling, the channels 4, 5 are filled flush with the surface of the core with the zinc oxide, zinc, plaster of Paris, and borax paste described above, the fillings being illustrated in Figure 1 and designated by the reference numeral 8, and the filled core is gently heated (say to about 200° C., i.e. slightly above the 163° C. at which the plaster of Paris decomposes to anhydrous $CaSO_4$) to dry and harden the filler. The core is now sprayed with a layer up to 0.005" thick, and preferably 0.001" to 0.002", of the powder sold as "Colmonoy 6" ("Colmonoy" is a Registered Trade Mark), of composition 63% to 73% Ni, 15% to 22% Cr, 3% to 5% B, and the balance Fe, with some C and Si, to promote adhesion of an immediately following further layer of "Nimonic 90" powder up to about 0.015", and preferably 0.008" to 0.010". Alternatively, the "Nimonic 90" may be sprayed direct on to the heated core. The sheath produced by the spraying is illustrated in Figures 2, 3 and 4 and designated 9.

The partly sprayed core is heated in vacuo at 950° C. to 1250° C. to reduce the zinc oxide to zinc without oxidation of the core or coating, to distil off the zinc (B.Pt. 907° C.), and to sinter the sprayed coating, at the same time bringing about diffusion between the "Colmonoy 6" layer and both the core and the coating, where "Colmonoy 6" is employed, or between the "Nimonic 90" and the core, where it is not. A suitable treatment is for 2 hours at 1150° C., under a vacuum of the order of 10^{-3} mm. carried out on a single blade in a furnace tube of 2" internal diameter, the filler employed containing about 1 gram of ZnO to be reduced to Zn. The residue of the plaster of Paris may be removed at this stage.

The spraying with "Nimonic 90" powder is continued until the full thickness of sheath (0.020" to 0.050") is applied, together with an allowance (for example .010") for final grinding and polishing, and the blade is re-sintered at 950° C. to 1250° C. in vacuo. It is necessary to provide a zinc trap in the exhausting system to prevent the volatilized zinc from clogging the exhausting pump. Where no intermediate layer is employed, the whole thickness of coating of "Nimonic 90" may be applied in one spraying operation requiring only one final sintering operation, which also serves for removal of the filler. However, application of the sprayed coating in more than one stage, although more time-consuming and therefore expensive, can be advantageous in enabling the filler to be removed at an early stage. The produced ducts are illustrated in Figures 2, 3 and 4 and designated 10.

A paste filler is advantageous where the main channels are connected to cross-channels, which in turn are connected to the main duct or ducts (as shown in the drawings), since complete filling of the channels—particularly at connections between channels—can be assured.

After final sintering, the blade is allowed to cool and is then ground and polished.

WHAT WE CLAIM IS:—

1. A method for the production of heat-

and corrosion-resistant components provided with cooling ducts, including the steps of forming channels in the surface of a core, filling the said channels with a temporary solid filling, building up a sheath of heat- and corrosion-resistant metal by spraying metal over the filled core, removing the temporary filling from the channels to leave ducts between the sheath and the core, and sintering the sprayed core to effect diffusion between the sprayed sheath and the surface of the core between the channels, whereby there is produced a component having an impermeable unitary coating bridging the channels in the core and secured to the surface of the core between channels by diffusion.

2. A method according to Claim 1, wherein an excess thickness of sheath is built up to allow for final shaping of the component to the required contour.

3. A method according to either of Claims 1 and 2, wherein the said core is formed from solid material.

4. A method according to either of Claims 1 and 2, wherein the said core is formed by powder metallurgy.

5. A method according to any of the preceding claims, wherein the said sheath is formed to full thickness in one spraying operation with final sintering.

6. A method according to any of Claims 1 to 4, wherein the said sheath is formed by stages in separate spraying operations, with or without the application by spraying of an intermediate layer or layers of material adapted on sintering to diffuse into the core and sheath, or into different layers of the sheath, each spraying operation being followed by sintering.

7. A method according to any of the preceding claims, wherein the said filling comprises a metal capable of being distilled off at or below the sintering temperature employed, for example cadmium or zinc, with or without a refractory cement, for example alumina cement.

8. A method according to any of Claims 1 to 6, wherein the said filling comprises a metal of melting point substantially higher than the sintering temperature employed, for example copper, aluminium, or steel wire, together with a refractory cement, for example alumina cement, the metal being strong enough to be capable of being withdrawn intact before or after sintering.

9. A method according to any of Claims 1 to 6, wherein the said filling comprises a refractory paste capable of being distilled at a temperature at or below the sintering temperature employed, but able to withstand the temperature at which spraying is carried out.

10. A method according to Claim 9, wherein the said paste comprises zinc oxide, zinc metal powder, plaster of Paris, and borax, all mixed with water.

11. A method according to any of the preceding claims, wherein sintering is carried out in vacuo.

12. A method according to any of Claims 1 to 10, wherein sintering is carried out in an atmosphere of hydrogen.

13. A method of production of heat- and corrosion-resistant components provided with cooling ducts, substantially as hereinbefore described.

14. Sheathed and ducted heat- and corrosion-resistant components, wherein the sheath is a sprayed metal unitary coating bridging channels in a core and diffused by sintering to the surface of the core between the channels.

15. Heat- and corrosion-resistant gas turbine blades having cooling ducts, substantially as hereinbefore described with reference to the accompanying drawings.

16. Heat- and corrosion-resistant components provided with cooling ducts, when produced by a method according to any of Claims 1—13.

NORMAN H. BUCKLEY,
Agent for the Applicants,
Chartered Patent Agent.

PROVISIONAL SPECIFICATION.

Improvements in or relating to Components for Operation at High Temperature.

We, THE BIRMINGHAM SMALL ARMS COMPANY LIMITED, a British Company, of Armoury Road, Small Heath, Birmingham 11, do hereby declare this invention to be described in the following statement:—

This invention relates to gas turbine blades and like components for operation at high temperature, of the type in which internal ducts are provided for the passage of gaseous or liquid coolant through the heat- and corrosion-resistant metal of the components, to enable them to withstand better the action of the hot fluids to which the surfaces of the components are exposed. It is particularly concerned with components in which the ducts are formed by channels in the surface of a core, the channels being enclosed by a sheath secured round the core. Formation of the ducts in this manner has the advantage that the channels may be readily

made of the relatively small cross-section required and occupy a position near the surface where they do not unduly affect the mechanical strength of the component, as is particularly important, for example, at the fixing root of a turbine blade. Moreover, the controlled placing of the ducts near the hot working surface enables the coolant to be most effectively used.

It is, however, a matter presenting considerable difficulty to secure adequate adhesion of the sheath to the core, yet unless this is done the sheath may break loose, and the cross-section of metal represented by the sheath may not provide any useful contribution to the strength of the section of the component taken as a whole.

The object of the invention is to produce a component with a channelled core, with a sheath applied to the core in a novel and advantageous manner, resulting in adequate adhesion to the core.

According to the present invention, a heat- and corrosion-resistant component with cooling ducts is formed by filling channels in the surface of a core with a temporary solid filling, building up a sheath of heat- and corrosion-resistant metal by spraying metal over the filled core, and removing the temporary filling from the channels to leave ducts between the sheath and the core, the sprayed core being subjected to sintering to effect diffusion between the sprayed sheath and the surface of the core between the channels.

The sheath is built up to a thickness sufficient for it to provide a stable outer part of the component, bridging the ducts. An excess thickness of sheath may be built up, to allow for final shaping and sizing of the component to the required contour by machining and/or grinding, and/or for polishing the outer surface.

The invention also includes sheathed and ducted heat- and corrosion-resistant components in which the sheath is a sprayed metal coating bridging channels in the core and diffused by sintering to the surface of the core between the channels.

An important advantage of the invention is that the sheath forms a seamless envelope of homogeneous metal and effectively encases the component. No welded or brazed joints are necessary, as is the case with sheaths of pre-formed sheet material.

The core may be made of any desired quality of heat-resisting steel or alloy, made from the solid material or by powder metallurgy technique, and the sheath may be formed by spraying a steel or alloy similar to the core, or any other heat-resisting or high-melting metal or alloy.

The sprayed sheath may be formed to full thickness in one continuous spraying operation, but advantageously it is formed by stages in separate continuous spraying operations, preferably with sintering after each operation. It is often convenient to remove the filler from the channels before the full thickness has been applied. In some cases, sintering of a sheath built-up to partial thickness may be the means of bringing about removal of the filler. If applied in stages, the successive layers are not necessarily of the same heat- and corrosion-resistant metal. Moreover, the successive layers may follow interlayers of sprayed material, e.g. a boride or a boron-containing alloy as described in Patent Application No. 30242/55 (Serial No. 803,649), serving to promote diffusion between the layers as the result of the sintering, and thus to promote good adhesion.

The filler should be of material capable of withstanding the temperature arising in the metal-spraying operation. Advantageously, the core is highly heated as an immediate preliminary to being sprayed, and the material of the filler must then withstand this elevated temperature.

Thus the filler may be a metal capable of being distilled off at a moderate temperature, e.g. cadmium, which may be distilled in vacuo at a temperature in the range 500° C. to 700° C. Zinc may likewise be used. Again, a relatively low-melting metal or alloy may be used. Such metals or alloys may be used in channels with one or more kinks to form kinked ducts from which the filler must be able to flow away in vaporised or molten form.

However, if the final form of any duct permits, tougher material such as copper, aluminium, or steel wire may be used as a filler that may eventually be withdrawn intact, this material being embedded in the channel by a refractory cement, e.g. alumina cement, to secure it in place, and to prohibit adhesion of the sprayed coating to the metal filler. Such a cement may also be used to secure wires of softer material, such as cadmium and zinc.

Again, the channels may be filled with a refractory paste containing a metal capable of being distilled at high temperature but able to withstand the temperature arising in spraying, including preliminary heating of the filled core. A preferred paste comprises zinc oxide and zinc particles and a relatively small amount of plaster of Paris, the zinc oxide and zinc preferably being present in about equal parts by weight. A little borax may be advantageously included to retard the setting. A very effective composition consists of:—

zinc oxide ..	$42\frac{1}{2}$	parts by weight
zinc filings ..	$42\frac{1}{2}$	,, ,, ,,
plaster of Paris	14.75	,, ,, ,,
borax	0.25	,, ,, ,,

the whole being mixed with a little water.

Such a filler does not significantly change in condition up to 1000° C. when heated in air. When heated in hydrogen, the zinc oxide is reduced to metallic zinc, and this, with the zinc filings, volatilises, leaving a residue of finely powdered calcium sulphate (from the plaster of Paris), capable of being shaken or blown from the ducts. The filler may be removed simultaneously with sintering of the sheath material.

The internal corners of the channels should be rounded to discourage fatigue cracks arising at any sudden change of section under the mechanical stress (accompanied by high temperature) to which the component is subjected in use. The external corners of the channels are also preferably rounded. This rounding should be applied even if the channels have undercut sides.

The channels in the core may be connected together by one or more cross-channels, e.g. at the root end of a turbine blade, for connection in turn to a channel for the supply of gaseous or liquid coolant, e.g. in the root mounting. The root itself of a blade (integral with the core) is preferably free from internal channels, thus avoiding weakening of this highly stressed part of the blade. In the case of a shrouded blade, the core channels may be similarly connected to one or more cross-channels leading to a channel in the shroud to complete the coolant circuit; or, in either shrouded or open blades, the channels may be blanked-off or connected to one or more blanked-off cross-channels, or allowed to open to the surface of the blade for deliberate escape of the coolant into the turbine atmosphere.

The invention will now be described in greater detail with reference to the preparation of a ducted gas turbine blade with a sintered sprayed metal coating applied with the aid of a paste filler as described above.

A blade core, consisting of the blade proper, and at least an anchoring root (but, if required, a shroud also) is formed of heat- and corrosion-resistant steel or other similar alloy, e.g., "G.42B" made in accordance with Patent Serial No. 746,472 and having the composition 25% Co, 19.5% Cr, 14.5% Ni, 0.3% C, 0.9% Mn, 0.3% Si, 3% W, 3% Mo, 0.3% Nb, 0.9% Ti, 0.04% B (by weight, all within the usual manufacturing tolerances), and the balance Fe. Again, there may be used the alloy sold under the Registered Trade Mark "Nimonic 90" believed to be of composition 15% to 21% Co, 18% to 21% Cr, up to 5% Fe, 0.1% C, 0.8% to 2% Al, 1.8% to 3% Ti, and the balance Ni. The blade has its usual aerofoil section smaller than that finally required, by an allowance of say 0.020" to 0.050" all round. Longitudinal channels are formed in the surface of the blade wherever a duct is required. In general, the main length of a channel is straight, but some at least of the channels, and particularly those nearer the leading and trailing ends of the section may be kinked to direct them to a main duct in the root, and possibly another main duct in a shroud. The bottom of the channel may be rounded, the edges of the channels are rounded into the surface of the core. This surface is shot-blasted, ready to receive the sprayed coating forming the sheath. Wide, shallow grooves are preferred for effective cooling of the completed blade.

The channels are filled flush with the surface of the core with the zinc oxide, zinc, plaster of Paris, and borax paste described above, and the filled core is gently heated (say to about 200° C., i.e. slightly above the 163° C. at which the plaster of Paris decomposes to anhydrous $CaSO_4$) to dry and harden the filler.

It is now preferred to heat the dried core to between 700° C. and 800° C. and to apply the sprayed coating to the hot core, as a means of improving adhesion. First, the core is sprayed with a layer up to 0.005" thick, and preferably 0.001" to 0.002", of the powder sold as "Colmonoy 6" ("Colmonoy" is a Registered Trade Mark), of composition 63% to 73% Ni, 15% to 22% Cr, 3% to 5% B, and the balance Fe, with some C and Si, to promote adhesion of an immediately following further layer of G.42B powder up to about 0.015", and preferably 0.008" to 0.010".

The partly sprayed core is heated in a flow of pure dry hydrogen at 950° C. to 1250° C. to reduce the zinc oxide rapidly to zinc without oxidation of the core or coating, to distil off the zinc (B.Pt. 907° C.), and to sinter the sprayed coating, at the same time bringing about diffusion between the "Colmonoy 6" layer and both the core and the coating. A suitable treatment is for 2 hours at 1150° C., with 1000 litres per hour hydrogen flow through a furnace tube of 2" internal diameter containing a single blade with filler containing about 1 gram of ZnO to be reduced to Zn. The residue of the plaster of Paris may be removed at this stage.

The spraying with G.42B powder is continued, with the blade heated to 700° C. to 800° C., until the full thickness of sheath (0.020" to 0.050") is applied, together with an allowance for final grinding and polishing, and the blade is re-sintered at 950° C. to 1250° C. in hydrogen or in vacuo. Again, 2 hours at 1150° C. is suitable, but a hydrogen flow is not necessary.

The blade is then ground and polished.

Application of the sprayed coating in more than one stage, as described above, is not essential, but is often advantageous in enabling the filler to be removed at an early stage.

A paste filler is advantageous where the main channels are connected to cross-

channels, which in turn are connected to the main duct or ducts, since complete filling of the channels—particularly at connections between channels—can be assured.

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803,650 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig. 1.

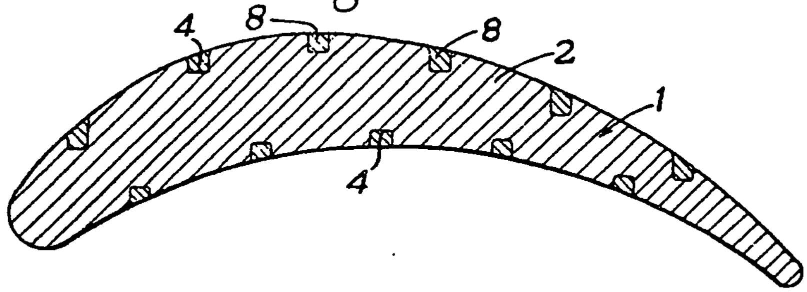

Fig. 2.

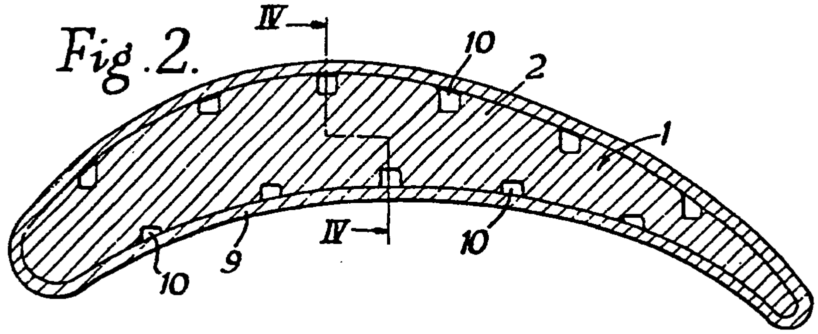

Fig. 3.

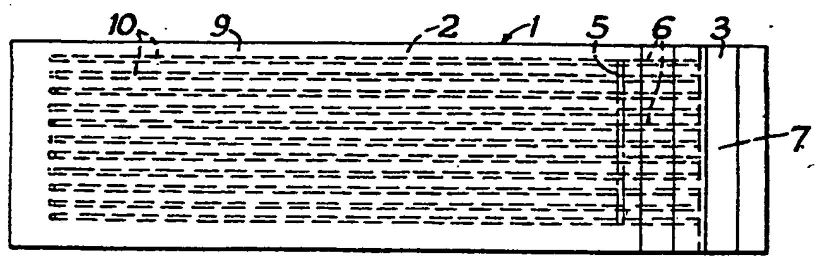

Fig. 4.